THE RELATIONSHIP BETWEEN CHRONOTYPE AND
VO_{2\text{MAX}}, FAT OXIDATION, AND RPE DURING
EXERCISE AT EXTREME ENDS
OF THE DAY

by

Jenna L. Carducci

An Abstract
of a thesis presented in partial fulfillment
of the requirements for the degree of
Master of Science
in the School of Nutrition, Kinesiology, and Psychological Science
University of Central Missouri

August, 2018
ABSTRACT
by
Jenna L. Carducci

The purpose of this research was to evaluate the relationship between chronotype and maximal VO₂, fat oxidation, and RPE during exercise at extreme ends of the day. Thirteen subjects completed two VO₂max tests, one in the morning (between 06:00-09:00) and one in the evening (between 21:00-24:00). Maximal VO₂, fat oxidation (reflected by RER), and RPE values (Borg 6-20), were determined. Chronotype was determined by the Morningness-Eveningness Questionnaire (MEQ). The intent was to compare variables by chronotype. A lack of recruitment of evening-types limited the ability to compare chronotypes, so variables were compared between morning and evening sessions only. There were no significant differences (p<.05) found between morning and evening sessions for maximal VO₂ (47.0 ± 7.0 vs. 47.3 ± 8.0 ml/kg/min), maximal fat oxidation (24.8 ±16.7 vs. 27.7 ± 22.3 Kcal), or maximal RPE (18.9 ± 1.1 vs. 18.8 ± 1.5). Exercising at extreme ends of the day may not result in a significant difference of VO₂max, fat oxidation, and/or maximal RPE among a group of mixed gender cohort recreationally, active adults.
THE RELATIONSHIP BETWEEN CHRONOTYPE AND VO_{2MAX}, FAT OXIDATION, AND RPE DURING EXERCISE AT EXTREME ENDS OF THE DAY

by

Jenna L. Carducci

A Thesis
in partial fulfillment of the requirements for the degree of Master of Science
in the School of Nutrition, Kinesiology, and Psychological Science
University of Central Missouri

August, 2018
THE RELATIONSHIP BETWEEN CHRONOTYPE AND VO_{2\text{MAX}}, FAT OXIDATION, AND RPE DURING EXERCISE AT EXTREME ENDS OF THE DAY

by

Jenna L. Carducci

August, 2018

APPROVED:

Thesis Chair: Dr. Matthew J. Garver

Thesis Committee Member: Dr. Whitley J. Stone

Thesis Committee Member: Dr. Meera Penumetcha

ACCEPTED:

Chair, School of Nutrition, Kinesiology, and Psychological Science: Dr. David S. Kreiner

Director of Graduate Education and Research: Dr. Odin L. Jurkowski

UNIVERSITY OF CENTRAL MISSOURI
WARRENSBURG, MISSOURI
ACKNOWLEDGMENTS

This research was supported by the Graduate Student Research Fund. I would like to thank Dr. Garver for the extensive time, thought, and support he put into reading, editing, and helping complete this thesis. I would like to thank the other two members of my committee, Drs. Stone, and Penumetcha for their commitment and effort to making this thesis better. I would also like to thank the numerous graduate and undergraduate Kinesiology and Nutrition students for their hard work and time put into preparation and data collection. A special thank you to all members in the Department of Nutrition and Kinesiology for their encouraging words and help with recruiting subjects. To my boyfriend, Chris Tuso, thank you for the constant support through the highs and lows of two academic degrees. Finally, the biggest thank you to my brothers, Brett and Taylor, and my parents, Angelo and Donna, for allowing me to follow my dreams and providing me with more love and support than I could ever imagine possible. This thesis would not have been possible with the help from every single one of these individuals and endless thank-you’s could never be enough.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>LIST OF TABLES</th>
<th>ix</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHAPTER 1: INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Significance</td>
<td>3</td>
</tr>
<tr>
<td>Purpose</td>
<td>4</td>
</tr>
<tr>
<td>Hypotheses</td>
<td>4</td>
</tr>
<tr>
<td>Delimitations</td>
<td>5</td>
</tr>
<tr>
<td>Limitations</td>
<td>5</td>
</tr>
<tr>
<td>Assumptions</td>
<td>6</td>
</tr>
<tr>
<td>Definition of Terms</td>
<td>6</td>
</tr>
<tr>
<td>CHAPTER 2: REVIEW OF LITERATURE</td>
<td>8</td>
</tr>
<tr>
<td>Introduction</td>
<td>8</td>
</tr>
<tr>
<td>Defining Circadian Rhythm and Chronotype</td>
<td>8</td>
</tr>
<tr>
<td>Circadian Rhythm</td>
<td>9</td>
</tr>
<tr>
<td>Circadian Rhythm Connected to Chronotype</td>
<td>16</td>
</tr>
<tr>
<td>Chronotype</td>
<td>18</td>
</tr>
<tr>
<td>Summary</td>
<td>20</td>
</tr>
<tr>
<td>CHAPTER 3: METHODS</td>
<td>22</td>
</tr>
<tr>
<td>Participants</td>
<td>22</td>
</tr>
<tr>
<td>Overview</td>
<td>23</td>
</tr>
<tr>
<td>Screening and Familiarization Visit</td>
<td>23</td>
</tr>
<tr>
<td>Standard, Pre-Test Meal</td>
<td>24</td>
</tr>
</tbody>
</table>
G. Human Subjects Amendment Approval ........................................................... 63
<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Demographics and Anthropometrics</td>
<td>30</td>
</tr>
</tbody>
</table>

ix
Exercise is commonly employed to enhance overall health and wellness. It is also the mechanism to increase athletic ability and performance. People implement the forms of exercise that provide them with the greatest benefit for the amount of time or effort invested (considered the return on investment). Hence, people search for approaches to modify physical activity or exercise engagement to experience results or objectives more quickly. In this regard, individuals seek out varied types of training (e.g. high intensity interval training, boot camps) or “quick-fix” programs. These training programs have also been shown to positively influence energy expenditure, general health (e.g. serum cholesterol, body fat, blood pressure), and exercise performance variables (e.g. aerobic capacity, anaerobic ability). Indeed, researchers have found differences in caloric expenditure (Castellani et al., 2006), ability to build muscle (Lowndes et al., 2009), and aerobic capacity (Swift et al., 2013) between individuals performing the same exercise.

There is evidence to indicate that results of exercise programs are more favorable when individualized to each person and their particular needs (Client Centered Exercise Prescription, 3rd Ed, 2015). Thus, one potential way to increase overall exercise benefits and performance is to understand an individual’s preferences towards exercise. In this regard, time of day of exercise may be an individual factor that should be considered when planning and executing exercise. Some research suggests that scheduling exercise during the time of day that is preferred by individuals can increase performance (Brown, Neft, and LaJambe, 2008; Vitale, Calogiuri, & Weydahl, 2013).
The preference of whether one enjoys exercise in the morning or night is based on circadian rhythm and described by the term chronotype. The circadian rhythm of an individual is an expression of certain physiological variables throughout a 24-hour period, such as sleep habits and alertness (Drust, Waterhouse, Atkinson, Edwards, & Reilly, 2005). Researchers have studied how, both at rest and during exercise, circadian rhythm can influence the body’s response to exercise based on the time of day (Lack, Bailey, Lovato, & Wright, 2009; Mongrain, Lavoie, Selmaoui, Paquet, & Dumont, 2003; Souissi et al., 2007).

In many cases, researchers describe people as having an “earlier” or “later” circadian rhythm. At rest, individuals with an earlier circadian rhythm normally have a peak melatonin release (Mongrain et al, 2003) and peak core temperature (Horne & Ostberg, 1976) occurring earlier in the day than those with later circadian rhythms. Regardless of the rhythm that people are associated with, research has demonstrated there may be a difference in physiological and psychological outcomes during exercise at opposite ends of the day. There is evidence to suggest that fat oxidation (Mohebbi & Azizi, 2011), total oxygen uptake (Soussi et al, 2007), and VO$_2$ kinetics (Brisswalter, Bieuzen, Giacomoni, Tricot, & Falgairette, 2007) are higher during exercise later in the day than in the morning.

Horne & Ostberg (1976) created a research methodology to associate an individual’s preference for time of day with their circadian rhythm. Researchers measured core temperature and created the Morningness-Eveningness Questionnaire (MEQ) to help determine an individual’s preference for wake time, level of peak alertness, and sleep times (Horne & Ostberg, 1976). After completion, researchers categorized individuals as “morning-type,” “evening-type,” or “intermediate” (a mixture of characteristics). Since the creation of the MEQ, numerous research studies (Brown et al., 2008; Lack et al., 2009; Rossi, Formenti, Vitale, Calogiuri,
Weydahl, 2015; Vitale et al., 2013) have utilized this survey to reveal patterns related to circadian rhythm and categorize chronotype of their subjects.

Many researchers have compared the results of the MEQ to psychological and physiological variables both at rest and during activity. When measuring rating of perceived exertion (RPE), researchers regularly find that exercise is perceived as harder for both morning-type individuals participating in exercise in the evening (Kunorozva, Roden, & Rae, 2014) as well as evening-types participating in exercise in the morning (Rossi et al., 2015). Similarly to circadian rhythm, chronotype has also been associated with sleep habits, where individuals deemed to be morning-types had earlier bedtimes, sleep onset times, sleep midpoints, and wake times than evening-types (Simpkin et al, 2014). Additionally, evidence has shown that exercise performance in walking and rowing tasks increased when an individual performed the activity at the time of day related to their chronotype (Brown et al, 2008; Vitale et al., 2013). Although there is evidence to suggest there is a difference between chronotypes in relation to exercise (ability to perform aerobic and anaerobic exercise), there is insufficient information to make conclusions.

**Significance of the Study**

By performing exercise at a preferred time of day, there may be potential to improve physiological (e.g. VO\textsubscript{2max} and fat oxidation) and psychological (i.e. RPE) performance variables. Circadian rhythm impacts melatonin release (Mongrain et al, 2004) and sleep habits (Lack et al, 2009; Simpkin et al, 2014); accordingly, it may also impact exercise response (Soussi et al., 2007). Horne & Ostberg (1976) created the MEQ to classify individuals’ chronotype based on preferences related to circadian rhythm. The MEQ has been used successfully in previous research (Baehr, Revelle, & Eastman, 2000; Bessot et al, 2006; Mohebbi et al, 2011). An
automated version of the MEQ is available for use and simplifies the process of categorizing research participants (http://www.cet-surveys.com/index.php?sid=61524) into their respective chronotypes.

Chronotype is associated with RPE during exercise (Kunorozva et al., 2013) and overall sleep habits (Lack et al., 2009), but evidence related to exercise response is not conclusive (Hill, Cureton, Collins, & Grisham, 1988; Vitale et al., 2013). Those who are morning-types report a lower RPE during exercise in the morning than in the evening (Kunorozva et al., 2014) and those who are evening-types report a lower RPE during exercise in the evening than in the morning (Rossi et al., 2015). Moreover, it remains unclear how chronotype may have on fat oxidation rates and VO$_2$ during exercise performed at different times of the day. The results of this investigation may provide insights into whether the different chronotypes experience changes in maximal VO$_2$, fat oxidation, and RPE during maximal testing at extreme ends of the day.

**Purpose of the study**

The purpose of this study was to determine if there was a significant difference in VO$_2$$_{max}$, assessed by absolute oxygen consumption, fat oxidation rates, assessed by respiratory exchange ratio, and/or RPE, assessed by Borg’s RPE, between morning- and evening-types, as defined by the MEQ, during exercise testing sessions between 06:00-09:00 and 21:00-24:00.

**Hypotheses**

- $H_0$: There will be no within-group or between-group differences between morning and evening values for maximal VO$_2$, fat oxidation, and RPE.
- $H_1$: The maximal VO$_2$ of morning types will be different during a maximal aerobic treadmill test in the morning than in the evening.
• H2: The maximal VO2 of evening types will be different during a maximal aerobic treadmill test in the morning than in the evening.

• H3: The maximal fat oxidation of morning types will be different during a maximal aerobic treadmill test in the morning than in the evening.

• H4: The maximal fat oxidation of evening types will be different during a maximal aerobic treadmill test in the morning than in the evening.

• H5: The maximal RPE of morning types will be different during a maximal aerobic treadmill test in the morning than in the evening.

• H6: The maximal RPE of evening types will be different during a maximal aerobic treadmill test in the morning than in the evening.

**Delimitations**

The delimitations of the prospective research are:

- Recreationally-active individuals between the ages of 18-25 (ACSM defined \( \text{150 minutes of moderate-intensity exercise/week} \));
- Two sessions total: One for morning, one for evening, in randomized order;
- VO\(_{2\text{max}}\) testing to determine VO\(_2\) consumption, RER, and RPE;
- ParvoMedics Metabolic cart to measure RER and VO\(_{2\text{max}}\);
- Borg’s RPE scale for measurement of RPE;
- Self-reported data collection for RPE and MEQ.

**Limitations**

The limitations of the prospective research are:

- The compliance of subjects to consuming provided test meal before testing;
• The accuracy of the ParvoMedics Metabolic cart to detect dependent variables RER and VO₂;
• The hours in the day that subjects are willing to participate in maximal exercise testing.

**Assumptions**

The assumptions of the prospective research are:

• The subjects are truthful on their Physical Activity Readiness Questionnaire (PAR-Q);
• The subjects are truthful on the morningness-eveningness questionnaire (MEQ);
• The test measurement instruments are reliable and valid for measuring the desired variables;
• The subjects consume the provided standard pre-test meal at the instructed time before testing;
• The subjects perform each aspect of the testing to maximal effort.

**Definition of Terms**

• Anaerobic Threshold: The upper limit of aerobic exercise and the point at which anaerobic energy production begins to be primarily utilized (Wasserman et al., 1964).

- Body Mass Index (BMI): Used to measure an individual’s weight relative to their weight to determine health status.
• CHO: Carbohydrate—A macronutrient utilized for energy
• Chronotype: The circadian rhythm of a given organism that determines if alertness and productivity are greater in the hours of early morning or later in the day (The American Heritage Dictionary of the English Language 5th Ed., 2017).

• Circadian Rhythm: A daily rhythmic activity cycle, based on 24-hour intervals that is exhibited by many organisms (The American Heritage Dictionary of the English Language 5th Ed., 2017).

• Energy Expenditure: The number of kilocalories burned during activity.

• Fat Oxidation: The utilization of fat for energy as determined by respiratory exchange ratio.

• Melatonin: A hormone released from the pineal gland that is associated with fatigue and sleepiness (Hardeland, Pandi-Perumal, & Cardinali, 2005; Vitale et al, 2017).

• Rating of Perceived Exertion (RPE): Measured on a scale, RPE is a tool for estimating effort and exertion, breathlessness, and fatigue during physical work (Borg, 1998).

• Respiratory Exchange Ratio (RER): The ratio between CO₂ production and O₂ uptake; Used to determine the relative contribution of carbohydrates and lipidsto energy expenditure (Ramos-Jiminez et al., 2008; Simonson & DeFronzo, 1990).

• VO₂: Oxygen consumption.

• VO₂ Kinetics: The rate at which VO₂ increases as physical activity intensity increases (Xu et al, 1999).

• VO₂max: Maximal oxygen consumption during activity.
CHAPTER 2
REVIEW OF LITERATURE

Introduction

The purpose of this study was to better understand the relationship between chronotype and exercise variables, specifically, VO\textsubscript{2max}, fat oxidation, and RPE as there is a lack of information on whether chronotype impacts these variables. What is known, however, is that circadian rhythm may influence exercise response. The close association between circadian rhythm and chronotype gives reason to investigate the latter’s relationship with exercise. This literature review will highlight the current information on the relationship between circadian rhythm and chronotype, as well as underscore previous research that associates both circadian rhythm and chronotype with exercise variables.

Defining Circadian Rhythm and Chronotype

Circadian rhythm, the “body clock,” is defined as “a daily rhythmic activity cycle, based on 24-hour intervals that is exhibited by many organisms” (The American Heritage Dictionary of the English Language 5\textsuperscript{th} Ed., 2017). The circadian rhythm of an individual is an expression of their melatonin levels, sleep habits, core temperature and other physiological responses to each hour in a 24 h period (Drust et al., 2005). The physiological responses associated with circadian rhythm often link individuals to a particular chronotype. In most individuals, chronotype is associated with a preference for a certain time of day.

Chronotype is “the circadian rhythm of a given organism that determines if alertness and productivity are greater in the hours of early morning or later in the day” (The American Heritage Dictionary of the English Language 5\textsuperscript{th} Ed., 2017). Chronotype may be able to predict the time of day an individual peaks in cognitive ability and capacity for physical activity such as
While physiological influence of circadian rhythm leads to an affinity for a time of day, chronotype is a way of describing an individual as “morning-type,” “evening-type,” or “intermediate-type”. Morning-types prefer waking up earlier in the morning while evening-types prefer waking later. Research supports the notion that individuals can be intermediate types, which occurs when a mixture of the characteristics associated with morning- and evening-type individuals coincide (Horne & Ostberg, 1976). Despite the potential for overlapping characteristics, most data suggest that significant physiological differences exist between morning- and evening-types (Baehr et al., 2000; Lack et al., 2009; Vitale et al., 2013).

Circadian Rhythm

Circadian rhythm influences physiological variables at rest and during exercise. Among these variables are melatonin release, sleep habits, and exercise response.

Circadian Rhythm and Melatonin

Circadian rhythm is associated with patterned release of hormones, including melatonin. Melatonin is released from the pineal gland (Hardeland et al., 2005) and is associated with increased fatigue and sleepiness (Mongrain et al., 2004). Mongrain and colleagues (2004) enrolled groups of 12 morning-types and 12 evening-types (determined by MEQ questionnaire) to assess release of melatonin. Participants were admitted into the lab four h prior to their 22 h stay. Sleep schedules for their stay closely mimicked each participants’ preferred wake and sleep times. Core body temperature and dim-light melatonin onset were measured throughout the stay. Temperature was measured every minute using a rectal probe. To measure dim-light melatonin onset, saliva samples were collected every half hour, starting five h before the scheduled bedtime. During measurements, participants were allowed to partake in quiet activities (e.g.
As the onset of increase of melatonin toward peak occurs later in evening-types compared with morning-types (Mongrain et al., 2004), it might be argued that the peak levels are reached later in evening-types than their morning-type counterparts. Recent evidence supports this speculation. Researchers utilized actigraphy and the measurement of melatonin through saliva collection as a method to determine the relationship between melatonin and sleep habits in toddlers (Simpkin et al., 2014). Sleep habits (e.g. bedtime, sleep time, wakefulness, wake time) were monitored and melatonin levels were measured for five consecutive days. Researchers discovered that melatonin release began to climb towards the peak level later for those categorized as evening-types (later sleep times) compared with morning-types. To summarize, an increase in melatonin was found to occur earlier in the day for those classified as morning-types compared to evening-types (Simpkin et al., 2014).

Circadian Rhythm and Sleep Habits

Through its impact on the release of melatonin, circadian rhythm influences alertness and sleep habits. Peak alertness occurs at the lowest sleepiness level during the day, as measured by a participant’s opinion (Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973). In simple terms, peak alertness is conceptualized as the time of day when an individual feels most awake and able to complete tasks (Drust et al., 2005).

Lack and colleagues (2009) utilized the Stanford Sleepiness Scale (Hoddes et al., 1973) to help assess both alertness and sleepiness. In their research, the investigators screened 313 individuals using the MEQ. The goal was to find those individuals who scored at the most
extreme ends of the MEQ continuum (extreme-morning and extreme-evening). Out of 313 individuals, two males and eight females were selected for the morning-type group while four males and eight females were selected for the evening-type group. Morning-type participants arrived at the lab approximately two h earlier (19:30) than evening-types (21:30). Core body temperature was measured using a rectal probe and recorded continuously while melatonin activity was assessed from urine every two h. Participants remained in bed for 27 h and were required to lay still. Each hour, participants were kept awake for 45min and then given a 15min sleep opportunity. A subjective measure of sleepiness was gathered immediately before each 15min sleep opportunity (using the Stanford Sleepiness Scale). Sleep propensity was monitored during the 15min bout of sleep opportunity. Researchers found that morning-types show significant and meaningful differences in peak alertness (occurring at approximately 13:00) compared to evening-types (peaking at approximately 22:30). In summary, circadian rhythm is clearly influenced by the interconnected relationship between melatonin, alertness, and sleep habits.

**Circadian Rhythm and Resting and Exercise Response**

It would be of interest to know if circadian rhythm alters aerobic and/or anaerobic metabolism during rest and exercise. It is well known that these variables are key to exercise performance. Although data is few, the current evidence is presented below.

Souissi et al. (2007) measured mean VO$_{2\text{MAX}}$ and mean aerobic work during a Wingate test to investigate total VO$_2$. This value was converted into kJ and adjusted for mechanical efficiency. Eleven healthy males participated in the research. According to the MEQ, they were all moderately morning-type or intermediate-type. Participants performed test sessions at 06:00 and 18:00 over two days with a recovery period of at least 36 h. Each testing session included a 30
second maximal sprint against a constant resistance (resistance determined by body mass). Peak power was measured as the highest average power during any 5s period and mean power was measured as the average power throughout the entire 30s test. Mean VO$_2$ increased significantly from the morning session (0.85 L) to the afternoon session (0.91 L). Calculations also revealed that mean aerobic work was significantly higher in the afternoon (4.2 kJ) compared with the morning (3.9 kJ) session (Soussi et al., 2007). Researchers concluded that aerobic energy production is involved more quickly and efficiently in the afternoon than in the morning.

Brisswalter et al., (2007) measured VO$_2$ in healthy, active males at rest, during light cycling exercise at 45 watts (W), and during vigorous exercise (80% of their ventilatory threshold). Subjects completed five lab visits: one for familiarization and four for testing. The testing sessions were performed on four different days. Each subject completed two sessions in the morning (07:00-08:30) and two sessions in the evening (19:00-20:30). Each testing session included 5min of cycling at 45 W, followed by 5min of rest, and finished with 10min of cycling at 80% of ventilatory threshold. At rest, VO$_2$ was 0.492 L/min in the morning and 0.451 L/min in the evening. During light cycling exercise at 45 W, the respective values for the morning and evening were 1.325 L/min and 1.395 L/min. It is important to note, these were not statistically different when enrolling a small sample of 14 participants (Brisswalter et al., 2007). On the contrary, during vigorous exercise (80% of ventilatory threshold), there was a significant difference between morning and evening testing sessions for VO$_2$ consumption and VO$_2$ kinetics. Sadly, exact values were not reported by the researchers. An increase in VO$_2$ kinetics and consumption represents a positive change for aerobic exercise. Analysis of VO$_2$ kinetics may provide insight into the physiological adjustments that an individual’s body undergoes to
allow maintenance of VO$_{2\text{max}}$ during aerobic endurance performance (Pelarigo, Machado, Fernandes, Greco, & Vilas-Boas, 2017).

Some emerging evidence indicates that anaerobic performance may be impacted by the time of day in which participation occurs (Chtourou & Soussi, 2012; Nishimura et al., 2014). For example, Nishimura and colleagues (2014) aimed to determine whether the anaerobic threshold occurred at a different intensity in the morning than in the evening. Nishimura et al (2014) recruited 10 healthy males to participate in two sessions of cycling exercise each, one in the morning (09:00-10:00) and one in the afternoon (16:00-18:00). Each cycling exercise consisted of stages of 90s of exercise at a pedaling rate of 60 rpm. The initial exercise intensity was set at 10 W and increased by 10 W for each stage until Borg RPE was indicated at 15-16 or the participant reached 80% of their age-predicted heart rate (HR) maximum. Among other variables, HR, ventilatory volume (VE), VO$_2$, and oral temperature were measured at rest and during exercise. The ventilatory threshold was calculated as the point of rapid elevation of VE in relation to workload. The definition of anaerobic threshold was taken from Wasserman & McIllroy (1964) who described it as the critical point wherein rising exercise intensity dictates the transition from aerobic to anaerobic energy metabolism. Presently, the important note to make is that anaerobic threshold was reached at a lower intensity in the morning than in the afternoon session.

To investigate the effect of time of day on time to exhaustion, researchers recruited 11 competitive male cyclists. Subjects participated in two weeks of testing, including six tests that were performed at 95% maximal power until exhaustion (Bessot et al., 2006). The six tests were divided into three in the morning (06:00) and three in the evening (18:00). A significantly greater mean time to exhaustion in the evening than in the morning was found. Researchers concluded
that time of day the exercise occurred had a significant impact on cycling performance and time to exhaustion.

Despite the fact that both studies utilized the MEQ to determine chronotype, neither reported the specific number of individuals in each chronotype as part of the results. Accordingly, while these results suggest that anaerobic performance may benefit from later day implementation, how this might be impacted by circadian rhythm or chronotype remains unclear.

*Circadian Rhythm and Fat Oxidation*

Research focusing on energy expenditure and RER response (reflective of fat oxidation) during exercise at different times of day is limited. Evidence shows that from low to moderate intensity exercise, the rate of fat oxidation increases. As intensity moves from moderate to vigorous levels; however, the rate of fat oxidation decreases (Achten, Gleeson, and Jeukendrep, 2002). Increasing fat and decreasing CHO utilization can increase power output and time of maintaining aerobic exercise before the body must rely on CHO for fuel (Spriet, 2002). This is an important note for determining fat oxidation during exercise at opposing ends of the day for performance. Performance may be increased during a specific time of day if fat oxidation is higher during that time.

In endurance athletes, performance may be highly dependent on the athlete’s ability to oxidize fat in order to spare CHO for use in more dire situations, such as an increase in intensity (Jeukendrep & Achten, 2001). Fat oxidation during exercise may also be dependent on substrate intake prior to exercise. There is evidence to suggest that the intake of high CHO (~1-4 g/kg within 1-4 hours) prior to exercise can suppress the oxidation of fat during the exercise bout (Acheson, Flatt, & Jequier, 1982). The ingestion of CHO prior to exercise (~0.8g/kg) causes a reduction in fat oxidation that must be compensated for by an increase in CHO oxidation for the
maintenance of energy production (Horowitz, Mora-Rodriguez, Byerley, & Coyle, 1997). However, it must be noted that fat oxidation still occurs, but the rate is lower if CHO are more readily available for substrate utilization (Acheson et al., 1982). With these considerations, there is importance placed on why determining when higher fat oxidation rates occur during the day, really matters.

Mohebbi and colleagues (2011) used a graded, maximal treadmill test to determine maximal VO$_2$ and fat oxidation during exercise at opposite ends of the day in men classified as obese (body mass index (BMI) $\geq$30 kg/m$^2$) and men classified as normal (BMI=20-25 kg/m$^2$). Twenty-two untrained men (10 with BMI $\geq$30 kg/m$^2$, 12 with BMI 20-25 kg/m$^2$) participated in an incremental exercise test with 3-min stages to determine VO$_{2\text{max}}$ and maximum fat oxidation rates. Each participant engaged in multiple trials in the morning (08:00) and evening (18:00). Trials were randomized and counter-balanced. Exercise began at a speed of 3.5 km/h and a grade of 1%. Speed was increased by 1 km/h every 3min until 6.5 km/h was reached. Thereafter, grade was increased 2% every 3 min until RER exceeded 1.0. At that intensity, speed was increased every min (1 km/h) until exhaustion. Results indicated that fat oxidation rates (mg/min) and energy expenditure (kcal/min) were higher in the evening session (18:00) versus the morning session (08:00) in both participant groups. More specifically, fat oxidation increased from 6.6 mg/min/kg in the morning to 7.2 mg/min/kg FFM in the evening in those who were classified as obese and from 6.1 mg/min/kg FFM to 7.2 mg/min/kg FFM (same respective test times) in males classified as normal BMI. Energy expenditure, during the respective tests, increased from 15 kcal/min to 16 kcal/min in men who were obese and 12 kcal/min to 13 kcal/min in males with normal BMI. There was no monitoring of dietary intake before testing, thus evidence to explain
changes in fat oxidation is not available. While these data lend support of the influence of circadian rhythm on substrate utilization, corroborative evidence is desirable.

**Circadian Rhythm Connected to Chronotype**

Core temperature is controlled by the hypothalamus and reflects the heat loss and heat gain mechanisms occurring in the body throughout a day and dependent on activities (e.g. exercise, change in environmental temperature etc.; Waterhouse et al., 2005). When core temperature drops below 35°C, hypothermia can occur, resulting in decreased muscle coordination and performance (Fudge, 2016). At the other extreme, when core temperature rises to around 40°C, volitional fatigue during exercise is more likely to occur (Hargreaves & Febbraio, 1998). Accordingly, the body regulates core temperature to around 37°C (Wenger, 1999).

Circadian rhythm is documented to impact core temperature. When studying mixed chronotype cohorts, core temperature was found to rise as the day progressed (Baehr, Fogg, & Eastman, 1999; Eastman, Hoese, Youngstedt, & Liu, 1995a; Eastman, Stewart, Mahoney, Liu, & Fogg, 1994; Martin and Eastman 1998; Mitchell, Hoese, Liu, Fogg, & Eastman 1997). Marotte and Timbal (1981) measured resting core temperature in seven healthy males over a period of 24 h. Researchers found that core temperature was at its minimum at approximately 05:00 h in individuals living a conventional lifestyle (awake during the daytime and asleep at night). Furthermore, they found that temperature continued to rise until it peaked between 14:00-20:00 h (after which plateaued before declining overnight back towards the minimum). Specifically, when individuals were restricted to an eight h sleep duration and their food intake is maintained to conventional timing of meals, maximum core temperature occurred around 17:00 (Drust et al,
An intriguing question arises, does temperature follow a distinct pattern according to whether individuals identify as morning- or evening-types? To address this question, Horne and Ostberg (1976) measured oral temperature in 48 subjects, over the course of three weeks, in half-hour intervals from the time of awakening to the time going to sleep. Simultaneously, Horne and Ostberg created a questionnaire, the morningness-eveningness questionnaire (MEQ), to establish chronotype of individuals. Horne & Ostberg found that those who were morning-types were more likely to be early-risers and have a significantly earlier peak oral temperature than evening-types, (19:32 vs. 20:40), respectively (1976). Results also indicated that morning-type individuals had a higher peak temperature throughout the day (36.9°C vs. 36.8°C and faster decrease in temperature after peak occurred (~0.09°C/h vs. ~0.03°C/h), respectively (Horne & Ostberg, 1976). Creation of the MEQ allowed future researchers to designate individuals into morning-type, evening-type, or a mix of characteristics (while circumventing the need for simultaneously monitoring temperature).

In a retrospective study, Baehr et al. (2000) analyzed baseline data from 101 men and 71 women who participated in various field studies of night-shift work. In each study, the MEQ was utilized to determine chronotype (Baehr et al., 1999; Eastman et al., 1994, Eastman et al., 1995a; Martin & Eastman 1998; Mitchell et al., 1997). In the studies, subjects remained in bed, in the dark, for 8 h. Core temperature was measured with a rectal probe at 1 min intervals. Individuals who were morning-types had a significantly earlier core temperature peak by approximately 3 h compared with evening-types (~18:00 vs. ~21:00). In summary, this may indicate that temperature changes follow a circadian rhythm and are also associated with different chronotype.
Chronotype

Physiological and psychological comparison, after designation by chronotype, reveals some interesting findings. Chronotype may be related to RPE (Rossi et al., 2015), sleep habits (Simpkin et al., 2014), self-paced walking (Vitale & Calogiuri, 2013), and performance variables, such as rowing time trials (Brown et al., 2008; Hill et al., 1988).

Chronotype and Rating of Perceived Exertion

The RPE scale is a subjective “tool for estimating effort and exertion, breathlessness, and fatigue during physical work” where a higher RPE indicates greater levels of fatigue (Borg, 1998). Oftentimes, participants experience a higher RPE during exercise at the time of day that is antagonistic to their chronotype (Kunorozva et al., 2013). For instance, Kunorozva and colleagues (2013) recruited twenty morning-type cyclists to participate in several cycling testing sessions focused on determining RPE changes for morning and evening sessions. The cyclists participated in six exercise sessions. The first session served as a familiarization, wherein the other five trials, randomized in order, occurred at 06:00, 10:00, 14:00, 18:00 and 22:00 with 24-48 h separating each. A protocol of increasing intensity was employed, and cyclists were free to choose their cadence, speed, and pedal rate so long as it kept them within a targeted HR range unique to the study. Borg RPE was recorded 30s before the end of each stage. Morning-type cyclists reported higher RPE during the 18:00 and 22:00 sessions compared with 06:00, 10:00, and 14:00). This finding may indicate that chronotype influences RPE during activity for morning-types. However, it may be differentially regulated between morning- and evening-types.
Chronotype and Sleep Habits

There is a strong relationship between chronotype and sleep habits, including wake times, peaks of alertness, and levels of sleepiness, respectively (Lack et al., 2009; Simpkin et al., 2014). In general, individuals who are morning-types have earlier wake times, earlier peaks of alertness, and lower levels of sleepiness in the morning compared with their evening-type counterparts (Lack et al., 2009). Simpkin et al. (2014) utilized actigraphy to monitor sleep habits in 48 toddlers. For two weeks prior to the study, parents completed the Children’s Chronotype Questionnaire, then, toddlers continued their regular sleep schedules while parents completed a daily 26-item sleep diary as part of data collection. Toddlers wore actigraphs on their non-dominant wrist to provide information on sleep habits. Melatonin onset was also measured through a saliva sample. Researchers found that toddlers with later circadian phases (later sleep times and later melatonin onset) were more likely to be categorized as evening-types according to the diary. Additionally, they found that toddlers expressing a strong morning preference had earlier bedtimes, sleep onset times, sleep midpoints, and wake times. Whether data from toddlers translates to adults is not fully understood. Nevertheless, according to the present work, an individual’s chronotype may be a strong indicator of when an individual may prefer to sleep.

Chronotype and Exercise Performance

Vitale, Calogiuri, & Weydahl (2013) investigated a self-paced walking task along three rolling hills. Twenty-two healthy college students completed the MEQ followed by a self-paced walking session. The task consisted of three repetitions up and down a hill at the chosen speed of the participant. The average time to complete the task when summing morning and evening tasks was 1086s (18min and 6s). Among the four participants categorized as morning-types, three finished the task faster in the morning test compared to the evening test ($M=61s$). Among the
four participants identifying as evening-types, three finished the task faster in the evening test compared to the morning test (average=73 s). Although the study was underpowered and there were no between group differences found for time to test completion, it is interesting that the majority of participants finished the task faster during the time of day they preferred.

Hill and colleagues (1988) measured VO\textsubscript{2max} during a cycling test (initial 4min at 60 W followed by an increase of 20 W every min until exhaustion). Those classified as evening-types were found to have a significantly higher VO\textsubscript{2max} during the evening bout of exercise. However, the same effect was not found for the morning-types. In fact, Hill and colleagues concluded that most physiological responses during exercise are the same for morning- and evening-types (1988).

Brown, Neft, and LaJambe (2008) investigated the impact of chronotype on rowing performance. Researchers instructed participants to attempt a 2000 m rowing time trial, once between 05:00 and 07:00, and once between 16:30 and 18:00, following their categorization into chronotypes by the MEQ. Rowers who were morning-types performed significantly better (by rowing 4.8s faster) during the morning attempt compared with the evening attempt (Brown et al, 2008). However, the same effect was not found for the evening-types. As noted above, there may be differential regulation between morning- and evening-types when investigating chronotype and exercise performance and response. At this time, there is a lack of evidence to make informed decisions about the connection between chronotype and exercise response.

**Summary**

The previous research shows that there is a possible relationship between chronotype and multiple physiological variables. When reviewing the evidence, there appears to be a lack of consensus on the specific connection between chronotype and specific variables as they relate to
exercise performance. Accordingly, it is practical to investigate how chronotype might relate to VO\textsubscript{2max}, fat oxidation, and RPE during maximal exercise performed at extreme ends of the day.
CHAPTER 3
METHODS

Participants

Recruiting for this investigation began with the approval of the Institutional Review Board at the University of Central Missouri, Warrensburg, Missouri. Ten recreationally active males (3 morning-type, 1 evening-type, 5 intermediate-type, and 1 undetermined) and 10 recreationally active females (3 morning-type, 0 evening-type, 6 intermediate-type, and 1 undetermined) were recruited from the University of Central Missouri. All individuals were between the ages of 18-25. Two participants (n=2) were eliminated due to non-compliance with the requirement of abstaining from vigorous exercise within 24 h of testing. One participant (n=1) was eliminated due to scheduling conflicts. Three participants (n=3) were excluded due to software malfunction leading to loss of data. One participant (n=1) was eliminated due to a loss of the nose clip during testing, leading to inaccurate VO₂ and RER results. Thus, we report on data from the remaining 13 individuals.

Based on a lack of consensus with data in literature, three G-Power sample size calculations manipulating effect size were conducted. The first (Effect size: .25, Alpha: .05, Beta: .8, Groups: 2, Repetitions: 2, Correlation: .8, Nonsphericity: 1) revealed the need for 16 subjects while the second (Effect size changed to .4) revealed the need for 8 subjects and the third (Effect size changed to .6) revealed the need for 6 subjects. Accordingly, the research team set a target accrual of 9 per group (morning- and evening-type).
Overview

The aim of this study was to investigate the relationship between the independent variable chronotype and the dependent variables maximal VO$_2$, fat oxidation, and RPE during exercise at extreme ends of the day (06:00-09:00 and 21:00-24:00).

Prior to the two testing sessions, a visit to screen for eligibility, sign the informed consent, gather demographic and anthropometric measures, and familiarize participants to testing occurred. The two testing sessions were randomized. Physiological data (VO$_{2\text{max}}$, RER, and RPE) were collected during a modified-Astrand protocol.

Screening and Familiarization Visit

The screening and familiarization visit included an activity questionnaire, a Physical Activity Readiness Questionnaire (PAR-Q), and the informed consent. The self-reflected activity questionnaire (Appendix A) defined individuals as recreationally active based on benchmarks presented by the American College of Sports Medicine (ACSM) (≥150min moderate-intensity exercise, ≥75min vigorous-intensity per week, or an adequate combination of the two). The PAR-Q tool (Appendix B) stratified an individual’s risk based on known diseases and/or signs or symptoms of disease. Individuals were excluded if they were required or recommended to receive medical clearance prior to vigorous activity. Finally, participants were asked to report any dairy intolerance, nut allergy, or other specific food allergies. Allergies compromised the ability to create a proper standard, pre-test meal; thus, was considered an exclusion criterion, if present.

After confirming eligibility, participants were provided an explanation of the informed consent and given time to read and sign the document. The collection of demographic data included: sex, race, and chronological age while anthropometric measures included height and
weight. Height was measured using a Seca stadiometer (Seca®, Chino, CA) and recorded in centimeters. Weight was measured using a Befour digital scale (Befour®, Saukville, WI) and recorded in kilograms. Participants were educated on pre-test preparation and assigned a session order based on randomization (initial morning or evening participation). Randomization was based off of a sequence of numbers from a random number generator (www.random.org).

The familiarization included being equipped with a heart rate monitor, headgear and a mouth piece, having resting HR and resting blood pressure recorded, jogging on the treadmill to determine the test session pace, and explanation of the variables being measured during testing (VO₂, RER, and RPE). Participants were asked what they considered to be their personal “slow, but comfortable jogging speed”. Speed started at their self-selected speed and was increased by 0.4 m/h every 2min. RPE was taken at the end of each 2min until participants felt as though they were at a comfortable jogging speed associated with a 12-13 on Borg’s RPE scale. This speed was recorded and utilized during the testing sessions for the modified-Astrand protocol.

As a final action, participants were provided a single, double-sided page of instructions and guidelines on how to appropriately prepare for the two testing sessions. The instructions included guidance on the recording of food and drink for a nutritional log, when to ingest the standard, pre-test meal, and the duration of time to avoid consuming caffeine and alcohol (at least 12 h prior) and refrain from vigorous exercise (at least 24 h).

**Standard, Pre-Test Meal**

Research has shown that an acute change (one h) in diet prior to performing exercise can alter substrate utilization during exercise testing (Gregory et al., 2011). To reduce error caused by variation of diets, subjects were provided a standard, pre-test meal, prepared by research staff, prior to the testing sessions.
The Mifflin & St. Jeor equation was utilized to calculate the 24 h estimated energy intake (EEI) for each subject (the equation is provided in Appendix C; Mifflin et al., 1990). The EEI is defined as the estimated dietary energy intake to maintain energy balance. The EEI for each subject was divided by four (¼ for breakfast, ¼ for lunch, ¼ for dinner, ¼ for snacks/added calories). The resulting value for the subjects ranged from 536.5 to 910.75 Kilocalories (kcal). These Kcals were subdivided into a given quantity of CHO, fats, and proteins. The Accepted Macronutrient Distribution Ranges (AMDR) notes that 45-65% of daily Kcal come from CHO, 20-35% come from fats, and 10-35% come from proteins (Nutrition and You, 2nd Ed.). Since high amounts of fat consumption prior to exercise can limit the use of CHO utilization (Hargreaves et al., 2003), the standard pre-test meals were created toward the higher end of the recommended AMDR range for CHO intake, and lower end of the recommended AMDR range for fat intake. The Recommended Dietary Allowance for protein was also considered and a formula of 1.4 g/kg of body weight (Nutrition and You, 2nd Ed.) was utilized. This value is within the recommended range for individuals who are active and aligns with the value calculated by AMDR recommendations. The standard pre-test meal was expected to have consisted of 60% CHO, 25% fat, and 15% protein (based on each individual’s EEI). An example calculation is shown in Appendix D. However, due to a miscalculation and a failure to include the amount of CHO coming from solid food (along with the added table sugar), to the total amount of CHO, the pre-test meal actually consisted of 80% CHO, ~3% Fat, and ~16-17% Protein.

Research shows that an increase in CHO ingestion soon before exercise (<1 h) can be detrimental to performance (Coggan & Swanson, 1992). On the other hand, CHO ingestion approximately 2-3 h prior to exercise can enhance performance (Hargreaves, Hawley, &
Jeukendrup, 2004). In accordance, the standard, pre-test meal was consumed 2 h before arriving to the testing session. The overall goal of the standard pre-test meal was to control macronutrient composition in the final meal before testing and provide the necessary fuel required for participants to be capable of performing maximal exercise. Moreover, the standard, pre-test meal helped to mitigate differences in substrate utilization due to dietary variations. Along with the standard, pre-test meal, participants were asked to repeat the same breakfast and lunch the day before the morning test as they consumed the day of the evening test. On the day of the evening test, participants consumed the standard, pre-test meal as a substitute for dinner. For dinner the evening before the morning-test, participants were free to choose their meal.

**Testing Sessions**

Participants reported to the UCM Kinesiology Human Performance Laboratories for the two testing sessions following the screening visit. Morning (start and completion time between 06:00 and 09:00) or evening (start and completion time between 21:00 and 24:00) sessions were completed in a counterbalanced fashion. To keep time between tests equivalent, an individual completing a morning session at 6:00 completed the evening session at 21:00. Likewise, tests completed at 07:00 and 08:00 were followed by testing at 22:00 and 23:00, respectively.

Upon arrival, participants were fitted for a heart rate monitor to record resting HR. Following HR measurement, resting blood pressure was also taken. Weight was recorded, and body composition analysis were recorded from the InBody (InBody 570®, InBodyUSA, Cerritos, CA) via bioelectrical impedance analysis. Thereafter, the treadmill protocol was explained thoroughly to each participant. Participants were then fitted with headgear and a mouthpiece and placed on the treadmill for testing. A calibrated ParvoMedics Metabolic Cart (TrueOne 2400®, ParvoMedics, Sandy, UT) was utilized to measure gas exchange during
VO$_{2\text{max}}$ testing. A modified-Astrand protocol (graded and maximal) with the intent to elicit a VO$_{2\text{max}}$ value at approximately 10 minutes was employed. The constant jogging speed determined during each familiarization trial was maintained and increases in grade (2%) every two minutes occurred until volitional exhaustion. In the last 30s of each stage, RPE (Borg’s scale 6-20), heart rate (Polar Monitor), and VO$_2$ and RER (ParvoMedics Metabolic Cart) were recorded. A 15-breath moving average sampling frequency was used to analyze VO$_2$ data (Scheidler, Garver, & Hanson, 2017). Regular encouragement was provided to each participant.

The current research utilized a novel concept, just published in early 2018, that a plateau of HR (within two beats per minute) appears to serve as stand-alone primary criteria for determining whether a true VO$_{2\text{max}}$ test has occurred (Keiller & Gordon, 2018). For this reason, HR was recorded every 5s after the subject tapped on the treadmill; the tap indicating they believed they had less than 30s of effort to give. With these criteria in place, a verification trial for VO$_{2\text{max}}$ was not included. Secondary criteria were supportive to the primary criteria and included: an RER of at least 1.05 (measured by the ParvoMedics Metabolic Cart) and an RPE of at least 17 (measured by Borg’s RPE scale).

Participants returned to the UCM Kinesiology Human Performance Laboratory for their second testing session at the opposing end of the day. Participants had at least 24 h of recovery between the testing sessions. The same protocol was utilized for the second session as occurred during the first testing session. To culminate the study, the MEQ (Appendix D) was completed. The MEQ utilized was an online version (http://www.cet-surveys.com/index.php?sid=61524). Individuals were divided into chronotype by the score received on the MEQ: Morning-types (59-86), evening-types (16-41), and neither-types (42-58).
Data Analysis

Characteristic to the randomized, counterbalanced design, each subject served as their own control. Due to the elimination of the only evening-type subject (software malfunction), subjects were grouped into one large cohort for analysis, rather than by chronotype. Therefore, multiple, paired samples $t$-tests were utilized to assess within subject factor variables (maximal VO$_2$, fat oxidation, and RPE) between conditions (morning and evening) and to assess for a potential order effect. Data were analyzed with IBM SPSS Statistics 23. An alpha level of $p < .05$ was used to determine significance.
CHAPTER 4
RESULTS

The methods of this research were designed to test three hypotheses that the chronotype of an individual would have an effect on maximal VO$_2$, fat oxidation, and RPE during maximal aerobic treadmill tests performed at extreme ends of the day (between 6:00-9:00 and 21:00-24:00). Data were collected in three sessions. During the first session, a familiarization trial, demographic (age, height, weight, and BMI) information, reported in Table 4.1, were recorded. In addition, with the mouthpiece and headgear in place, participants reported RPE during short, incremental, steady-state jogging stages. The jogging speed associated with a 12-13 on the RPE scale (determined to be speeds from 4.7-6.4 mph) was recorded for use during the performance testing.

All data related to the dependent variables (maximal VO$_2$, fat oxidation, and RPE) were collected during the performance tests completed in separate, 60min sessions. Separate, paired samples $t$-tests were utilized to assess order effect and presence of significant outcomes. The results for the tests of significance related to order effect, VO$_{2\text{max}}$, fat oxidation, and RPE are reported.

Demographics

Twenty recreationally active individuals (females=10; males=10) completed one or both performance tests, but only 13 participants (females=8; males=5) successfully completed the study with full compliance. The original twenty participants included 11 intermediate-types, 6 morning-types, 1 evening-type, and 2 incompletes (failed to complete test). The final 13 participants included 5 morning-types and 8 intermediate-types. The participants removed (n=7) were due to reported non-compliance from engagement in vigorous exercise within 24h of
testing after both tests were completed (n=1; morning-type), reported non-compliance from engagement in vigorous exercise within 24h of testing after one test was completed (n=1; incomplete), scheduling conflicts (n=1; incomplete), software malfunction (n=3; three intermediate-type, one evening-type), and loss of nose clip during testing (n=1; intermediate-type).

Convenience sampling undermined recruitment of evening-type individuals (n=1), further, data for this participant was excluded from subsequent analyses due to equipment malfunction as noted above. Data were merged into one group rather than being analyzed by chronotype. Although we cannot answer the original hypothesis, it may be important to note that we are still interested in the fuel utilization and perceived effort of morning- and intermediate-types during the two conditions.

Table 4.1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yrs</td>
<td>20.64</td>
<td>1.39</td>
</tr>
<tr>
<td>Height, cm</td>
<td>169.68</td>
<td>7.39</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>71.99</td>
<td>11.96</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>24.93</td>
<td>3.02</td>
</tr>
<tr>
<td>Body Fat Percentage (%)</td>
<td>22.69</td>
<td>10.24</td>
</tr>
</tbody>
</table>

Note: Yrs=years, cm=centimeters, kg=kilograms, BMI=Body Mass Index, and m=meters

Order Effect

To mitigate the chance that a potential learning effect would influence results, subjects were randomly assigned to participate in the morning or evening condition first. Despite this attempt, when comparing results from session 1 vs. session 2, there was an order effect found for RPE ($p=.047$).
Maximal VO$_2$

Upon visual inspection, 11 of 13 participants in the morning and 10 of 13 participants in the evening had an HR plateau within 2 bpm in the last 30s of each test. However, the 2 participants in the morning and 3 participants in the evening that did not meet the primary HR criteria, met the secondary criteria of completing a VO$_{2max}$ of an RER $\geq$ 1.05 and an RPE of $\geq$ 17. Data were analyzed with a 15-breath moving average. Using breath-by-breath data, averages were taken every 15 breaths, beginning at the first stage, and the maximal average value of the 15-breath moving VO$_2$ was recorded as the VO$_{2max}$. The paired samples $t$-test indicated that VO$_{2max}$ did not differ between morning (M=47.0, SD=7.0 ml/kg/min) and evening (M=47.3, SD=8.0 ml/kg/min) conditions, $t$(12)=.37, $d$=.04, $p$=.24.

Maximal Fat Oxidation

To determine fat oxidation, RER and VO$_2$ values were taken from breath-by-breath data. The average RER over 15 breaths was aligned with the average VO$_2$ of the associated breaths. The average RER was then compared with the known stoichiometric principles related to VCO$_2$ and VO$_2$ and fuel usage to create an equation for determining caloric expenditure by fat. The summed number of Kcal expended by fat oxidation was determined using RER and used for the maximal fat oxidation value. The paired samples $t$-test indicated that fat oxidation (max number or Kcal expended from fat) did not differ between morning (M=24.8, SD=16.7 Kcal and evening (M=27.7, SD=22.3 Kcal) conditions when analyzing data from the 15 breath moving average, $t$(12)=.54, $d$=.15, $p$=.20.

Maximal RPE

Data were recorded from the subjects’ noted RPE in the last 30s of each stage and the last 30s of the overall tests using Borg’s RPE scale. The paired samples $t$-test indicated that RPE did
not differ between morning (M=18.9, SD=1.1) and evening (M=18.8, SD=1.5) conditions, 
t(12)=.27, d=.04, p=.25. As previously mentioned, a paired samples $t$-test between session 1 and 
session 2 revealed that there was a learning effect between sessions. It may be that participants 
felt like they were working harder in session 2 (18.5 vs. 19.1; $p=.047$).
The aim of this investigation was to examine the potential relationship between chronotype and the dependent variables maximal VO$_2$, fat oxidation, and RPE during exercise at extreme ends of the day in recreationally active adults. Maximal, aerobic treadmill tests were performed at extreme ends of the day by each participant ($n=13$). Chronotype was collected from the MEQ score for each individual as a component of the final analysis. Due to an inability to recruit evening-type participants, there was not data to be utilized, so data were merged into one group (morning- and intermediate-types), thereby negating statistical analyses between morning and evening types. Rather, dependent variables were compared between responses in the morning and evening of the combined group. There were no statistically significant differences in any variables between morning and evening sessions.

While the hypotheses presented in Chapter 1 were unable to be addressed, differences in the dependent variables between the morning and evening sessions for the whole group are of interest as the results may be generalized for non-evening types or compared to studies that do not involve chronotype. The remainder of this discussion focuses on results for morning versus evening sessions only, irrespective of chronotype.

**Maximal VO$_2$**

The VO$_{2\text{max}}$ during morning and evening sessions was not statistically different. It is important to note that most participants (morning session: $n = 11$, evening session: $n = 10$) met the primary criteria for completing a VO$_{2\text{max}}$ test (Keiller & Gordon, 2018) and all participants failing to meet the primary criteria met the secondary criteria (RER $\geq 1.05$ and RPE $\geq 17$). With this finding, the present results support Keiller & Gordon’s (2018) recently presented criteria for
a VO$_{2\text{max}}$ of a HR plateau within 2 bpm in the last 30s of the test. We can offer support for its use in future research. The benefit of utilizing this new HR criteria is that previous research shows that using secondary criteria can underestimate VO$_{2\text{max}}$ by up to 27% (Poole, Wilkerson, & Jones, 2008). Keiller & Gordon (2018) suggested that the limiting variable of VO$_{2\text{max}}$ is HR and reason that VO$_{2\text{max}}$ occurs as a direct consequence of HR achieving maximum levels and concluded that if HR achieves a maximum and is sustained, VO$_{2\text{max}}$ must be achieved as well. It would be prudent to include secondary criteria in case of a loss of heart rate data. The results of the current study align with the findings of Mohebbi & Azizi (2011) who, after performing VO$_{2\text{max}}$ treadmill tests in the morning and evening, concluded that VO$_{2\text{max}}$ does not significantly alter between morning and evening sessions. Like the present study, results were not compared by chronotype.

In contrast, Hill and colleagues (1988) measured VO$_{2\text{max}}$ and chronotype during a cycling test to exhaustion (one in the morning and one in the evening) and did, in fact, see a significantly higher VO$_{2\text{max}}$ during the evening session (2.69 0.15 L/min) vs the morning session (2.56 0.14 L/min) for evening-types among 32 college students. However, the same effect was not found for morning-types. Considering the current study only utilized results from morning- and intermediate-types, the combined results support the notion that there may not be a significant difference in VO$_{2\text{max}}$ between morning and evening exercise sessions for morning-types. Future studies should work to include a comparison between morning-types and evening-types or focus solely on evening-types to measure if there is a significant difference for evening-types only.

**Maximal Fat Oxidation**

The results of this research suggest that there is not a significant difference in maximal fat oxidation during exercise at opposite ends of the day. These data can be generalized to a
mixed cohort of recreationally active individuals of varying body composition who are morning-
or intermediate-types. Unlike VO$_{2\text{max}}$, these results do not parallel the results of the study by Mohebbi & Azizi (2011). Mohebbi and Azizi (2011) found that fat oxidation rates were higher during the evening session (18:00) versus the morning session (08:00). The demographic recruited and the time of day of testing, may have accounted for the finding. These researchers utilized two specific groups of males, those classified as normal weight and those classified as obese (all non-active) and compared their results. Moreover, Mohebbi & Azizi (2011) monitored core temperature changes in the evening, potentially explaining why there were elevated fat oxidation rates in the evening session. The reasoning behind this is that there is an association between an increased core temperature and an increased level of catecholamines (Jeukendrep, 2003). An increase in catecholamines (specifically epinephrine) stimulates lipolysis; therefore, hormones may be the underlying cause of higher levels of fat oxidation with an increased core temperature (Jeukendrep, 2003).

Marotte & Timbal (1981) found that core temperature is at a minimum at approximately 05:00 h and hits a peak at approximately 14:00-20:00 h in a non-labeled group (chronotype not measured). Similarly, in a retrospective study by Baehr et al. (2000), researchers analyzed baseline data of the relationship between chronotype and core temperature. Results suggested that morning-types had a significantly earlier core temperature by approximately 3 h (~18:00 vs. ~21:00) compared to evening-types. Considering the current study only contained a cohort of morning- and intermediate-types, it is plausible to speculate that most, if not all, of our subjects hit their core temperature peak before their evening testing session occurred. If there was no difference in core temperature, it may explain why there was no difference in fat oxidation. In the present study, core temperature was not monitored.
In opposition to the current work, Mohebbi and colleagues (2011) performed their evening session at 18:00 which coincides with the core temperature peak in morning types. As our evening session occurred past the peak hour of 18:00 (21:00-24:00), we surmise that core temperature would have been lower during our evening session, and possibly closer to the core temperature during the morning session (06:00-09:00). With this information, it may explain why Mohebbi and colleagues (2011) found a difference in fat oxidation rates between sessions and we did not. Considered collectively, we can propose differences that have been found in fat oxidation between morning and evening exercise sessions (Mohebbi & Azizi, 2011) may be attributed to differences in core temperature which was masked in the current study because of the late start of the evening session. Future studies should either monitor core temperature or be aware if there is a difference in fat oxidation, it may be attributed to core temperature changes.

Breath by breath data were analyzed to determine RER and substrate being metabolized. An RER of 0.75-0.85 reflects primarily fat oxidation, around 0.85 reflects a combination of fats and CHO utilization, and 0.90 and above reflects primarily CHO metabolism (Péronnet & Massicotte, 1991). During most sessions in the morning (n=9/13) and evening (n=9/13), participants achieved and maintained an RER of 0.90 by the end of the second stage, reflecting that they were primarily utilizing CHO, at a relatively low intensity, when it would be expected they would be oxidizing fats. It was difficult to detect differences in fat oxidation when CHO were the primary macronutrient being utilized.

As mentioned in Chapter 3, a choice was made, based on AMDR recommendations, to create the standard, pre-test meal consisting of approximately 60% CHO, 25% fats, and 15% proteins. However, due to a miscalculation and failure to include the CHO from solid foods in the total CHO, the meal contained 80% CHO, ~3% fats, and ~16-17% proteins. Data suggests
that even when a high CHO meal is consumed, the increased intake merely reduces the rate of fat oxidation but does not completely suppress it (Acheson et al., 1982). This explains why subjects were achieving a higher than expected RER of 0.90, when fats would have conceivably been the substrate of choice for the intensity.

There are also recommendations in place for the amount of grams of CHO per kg of body weight prior to exercise for proper supplementation (ACSM, 2016). It should be noted that these recommendations are based on pre-exercise fueling for exercise lasting longer than 60 minutes (ACSM, 2016). The participants of the current study completed the test in less than 15 minutes; but the following idea may still be worthwhile to consider. These recommendations include 1-4 g/kg of CHO 1-4 hr prior to exercise, with 4 g being appropriate for 4 hr before, 3 g for 3 hr before and so on (ACSM, 2016). Under these recommendations, the participants in the current study should have consumed ~2 g/kg of CHO prior to testing. Only 2/13 participants consumed more than 2 g. This suggests that although the participants consumed more CHO than planned, and possibly too much to properly measure fat oxidation, the participants were receiving approximately the proper amount of CHO to prepare for the test. Research should work to standardize pre-test meals within AMDR recommendations to ensure participants are receiving enough of each macronutrient in the pre-test meal.

Maximal RPE

Despite efforts to familiarize participants with the testing protocol, a paired samples t-test did reveal a learning effect between session 1 and session 2, with session 2 being higher (session 1: $M=18.5$, session 2: $M=19.1$). This may have resulted from participants feeling as if they were working harder during their second session due to experiencing the difficulty of a maximal test in the first session.
Hill et al. (1989) presented that RPE was significantly higher during maximal exercise in the evening than in the morning in a study where chronotypes were not monitored. Not monitoring chronotype may have limited the results of the research performed by Hill et al. (1989), therefore the current investigation attempted to improve on previous literature by monitoring chronotype. Once data were collapsed, this limitation was propagated in our work, rather than addressed. Nevertheless, the present results suggest that there is not a difference in reported maximal RPE during exercise at extreme ends of the day.

**Limitations of the Study**

The convenience sample model utilized in this study limited recruiting evening-type individuals. Furthermore, due to equipment malfunction, the single evening-type participant completing the study was excluded. The ability to compare chronotypes and analyze variables according to the hypotheses was not possible. As chronotype follows a pattern by age, and there is a natural shift from morning-type to evening-type in early adulthood (Lack et al., 2009), it would have been expected to have been able to recruit more evening-types than actually occurred. Due to equipment malfunction, non-compliance, and scheduling issues, we were forced to reduce our number of eligible participants from 20 to 13. The sample size was smaller than desired and decrease the ability to generalize the results.

The addition of extra CHO in each meal (approximating 80% CHO, ~3% fat, and ~16-17% PRO) limited the ability to explore differences in fat oxidation. Due to a miscalculation and failure to include the CHO from solid foods in the total CHO, the AMDR recommendations were not followed as intended. A high amount of CHO prior to exercise may result in elevated CHO oxidation during exercise (Acheson et al., 1982). This increase in CHO utilization may have reduced the rate of fat oxidation (Acheson et al., 1982), impacting the ability to detect
differences in fat oxidation between sessions. In addition, participants were instructed to eat similar meals the day before the morning test as the day of the evening test, but this was only confirmed verbally and there is no guarantee that the meals the participants consumed did not affect fat oxidation.

**Recommendations for Future Research**

1. Monitoring of nutrition by either providing more standardized meals or creating meal plans should occur with more strict guidelines. Creation of a pre-test meal with measurements of fat on the higher end of the AMDR (~35%) and CHO on the lower end of the AMDR (~45%) may help the potential to find differences in fat oxidation by closing the gap of difference in portions.

2. An increase in recruitment sample is needed so results are applicable to larger populations. A focus on recruitment of both chronotypes is necessary, too.

3. In the present analysis, the MEQ was conducted after both tests were performed to ensure that enough participants were recruited to complete the study. Conducting the MEQ questionnaire prior to testing may help ensure there is an adequate number of each chronotype, so comparison is possible.

4. It may be valuable to monitor core temperature in unison with the MEQ to ensure the results of the MEQ are presenting the correct chronotypes for comparison.

**Conclusion**

The current study suggests there is no difference between maximal VO$_2$, fat oxidation, or RPE during exercise at extreme ends of the day in morning or intermediate chronotype individuals. Originally, chronotype was to be included in analyses to address limitations in previous research. External factors precluded such analyses. Therefore, the hypotheses remain
neither supported nor unsupported; future work should focus to recruit varying chronotypes with intentionality (as an inclusion criterion, perhaps). In summary, this research primarily provided future recommendations for research to be able to truly identify the differences in maximal VO\textsubscript{2}, fat oxidation, and RPE during exercise tests at opposite ends of the day.
REFERENCES


Brisswalter, J., Bieuzen, F., Giacomoni, M., Tricot, V, & Falgarette, G. (2007). Morning-to-
evening differences in oxygen uptake kinetics in short-duration cycling exercise.

*Chronobiology International*, 24(3), 495-506.

1894-1900.

Energy expenditure in men and women during 54 h of exercise and caloric deprivation.


Chtourou, H., & Souissi, N. (2012). The effect of training at a specific time of day: a review. *The

exercise: effects on performance. *Medicine & Science in Sports & Exercise*, 24(9), 331-
335.


circadian rhythms with exercise during the night shift. *Physiology & behavior*, 58, 1287-
1291.

Eastman, C. L., Stewart, K. T., Mahoney, M. P. Liu, L., & Fogg, L. F. (1994). Dark goggles and
bright light to improve circadian rhythm adaptation to night-shift work. *Sleep*, 17, 535-
543.


Scheidler, C. M., Garver, M. J., & Hanson, N. J. (2017). The gas sampling interval effect on VO$_{2\text{peak}}$ is independent of exercise protocol. *Medicine & Science in Sports & Exercise*, 49(9), 1911-1916.


APPENDIX A
ACTIVITY QUESTIONNAIRE

For the question below, the following definitions apply.

- **Moderate-intensity includes:** Walking (3 mi/h), jogging (5 mi/h), cycling (5 mi/h), light weight-training, or equivalent intensity.

- **Vigorous-intensity includes:** Race walking, running, swimming brisk laps, cycling (10 mi/h), hiking, heavy weight-training, competitive sports, or equivalent intensity.

On a regular basis, through planned exercise or an accumulation of at-least 10 minute bouts of physical activity, do you complete at least 30 minutes of moderate-intensity exercise on at least 5 days per week, OR 25 minutes of vigorous-intensity exercise on at least 3 days per week, OR an adequate combination of the two?

Yes ☐ No ☐
APPENDIX B

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)

2017 PAR-Q+
The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.

1) Has your doctor ever said that you have a heart condition □ OR high blood pressure □?

2) Do you feel pain in your chest at rest, during your daily activities of living, OR when you do physical activity?

3) Do you lose balance because of dizziness OR have you lost consciousness in the last 12 months? Please answer NO if your dizziness was associated with over-breathing (including during vigorous exercise).

4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? PLEASE LIST CONDITION(S) HERE:

5) Are you currently taking prescribed medications for a chronic medical condition? PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:

6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer NO if you had a problem in the past, but it does not limit your current ability to be physically active. PLEASE LIST CONDITION(S) HERE:

7) Has your doctor ever said that you should only do medically supervised physical activity?

If you answered NO to all of the questions above, you are cleared for physical activity.
Go to Page 4 to sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow International Physical Activity Guidelines for your age (www.who.int/dietphysicalactivity/en/).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant • talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at www.eparmedx.com before becoming more physically active.
- Your health changes • answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

Copyright © 2017 PAR-Q+ Collaborative 01-01-2017
2017 PAR-Q+

If you answered NO to all of the follow-up questions about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered YES to one or more of the follow-up questions about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the ePARmed-X+ at www.eparmedx.com and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at www.eparmedx.com before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt about completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

All persons who have completed the PAR-Q+ please read and sign the declaration below.

If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that a Trustee (such as my employer, community/fitness centre, health care provider, or other designate) may retain a copy of this form for their records. In these instances, the Trustee will be required to adhere to local, national, and international guidelines regarding the storage of personal health information ensuring that the Trustee maintains the privacy of the information and does not misuse or wrongfully disclose such information.

NAME ___________________________ DATE ________________

SIGNATURE ___________________________ WITNESS ___________________________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ___________________________

For more information, please contact

www.eparmedx.com
Email: eparmedx@gmail.com

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jannik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the BC Ministry of Health Services.

Citation for PAR-Q:


Key References:


Copyright © 2017 PAR-Q+ Collaboration
01-01-2017
APPENDIX C

MIFFLIN ST. JEOR EQUATION FOR ESTIMATED ENERGY INTAKE

Men: 10w + 6.25h - 5a + 5 multiplied by activity factor

Women: 10w + 6.25h - 5a - 161 multiplied by activity factor

Where w=weight in kg, h=height in cm, and a=age in years

<table>
<thead>
<tr>
<th>Activity Factor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2</td>
<td>If sedentary, little or no exercise and desk job</td>
</tr>
<tr>
<td>1.375</td>
<td>If lightly active, little exercise, or sports 1-3 days a week</td>
</tr>
<tr>
<td>1.55</td>
<td>If moderately active, moderate exercise, or sports 3-5 days a week</td>
</tr>
<tr>
<td>1.725</td>
<td>If very active, hard exercise, or sports 6-7 days a week</td>
</tr>
<tr>
<td>1.9</td>
<td>If extremely active, hard daily exercise or sports and physical job</td>
</tr>
</tbody>
</table>

Example:

A 6’0, 150-lb, 25-year-old male who regularly exercises 3 days a week.

10(68.2) + 6.25(177.8) – 5(25) + 5 * (1.55) = 2,585 kcal/day

His standard, pre-testing meal would consist of 646 total Kcal. 387 kcal would come from CHO (97 grams (g)), 162 kcal (18 g) would come from fat, and 97 kcal (24 g) would come from protein.
MORNINGNESS-EVENINGNESS QUESTIONNAIRE
Self-Assessment Version (MEQ-SA)\(^1\)

Name: ___________________________ Date: ___________________________

For each question, please select the answer that best describes you by circling the point value that best indicates how you have felt in recent weeks.

1. *Approximately* what time would you get up if you were entirely free to plan your day?

   [5] 5:00 AM–6:30 AM (05:00–06:30 h)
   [4] 6:30 AM–7:45 AM (06:30–07:45 h)
   [3] 7:45 AM–9:45 AM (07:45–09:45 h)
   [2] 9:45 AM–11:00 AM (09:45–11:00 h)
   [1] 11:00 AM–12 noon (11:00–12:00 h)

2. *Approximately* what time would you go to bed if you were entirely free to plan your evening?

   [5] 8:00 PM–9:00 PM (20:00–21:00 h)
   [4] 9:00 PM–10:15 PM (21:00–22:15 h)
   [3] 10:15 PM–12:30 AM (22:15–00:30 h)
   [2] 12:30 AM–1:45 AM (00:30–01:45 h)
   [1] 1:45 AM–3:00 AM (01:45–03:00 h)

3. If you usually have to get up at a specific time in the morning, how much do you depend on an alarm clock?

   [4] Not at all
   [3] Slightly
   [2] Somewhat
   [1] Very much

---

\(^1\)Some stem questions and item choices have been rephrased from the original instrument (Horne and Östberg, 1976) to conform with spoken American English. Discrete item choices have been substituted for continuous graphic scales. Prepared by Terman M, Rifkin JB, Jacobs J, White TM (2001), New York State Psychiatric Institute, 1051 Riverside Drive, Unit 50, New York, NY, 10032. January 2008 version. Supported by NIH Grant MH42931. See also: automated version (AutoMEQ) at www.cet.org.

4. How easy do you find it to get up in the morning (when you are not awakened unexpectedly)?

   [1] Very difficult
   [2] Somewhat difficult
   [3] Fairly easy
   [4] Very easy

5. How alert do you feel during the first half hour after you wake up in the morning?

   [1] Not at all alert
   [2] Slightly alert
   [3] Fairly alert

6. How hungry do you feel during the first half hour after you wake up?

   [1] Not at all hungry
   [2] Slightly hungry
   [3] Fairly hungry
   [4] Very hungry

7. During the first half hour after you wake up in the morning, how do you feel?

   [1] Very tired
   [2] Fairly tired
   [3] Fairly refreshed
   [4] Very refreshed

8. If you had no commitments the next day, what time would you go to bed compared to your usual bedtime?

   [4] Seldom or never later
   [3] Less that 1 hour later
   [2] 1-2 hours later
   [1] More than 2 hours later
MORNINGNESS-EVENINGNESS QUESTIONNAIRE

Page 3

9. You have decided to do physical exercise. A friend suggests that you do this for one hour twice a week, and the best time for him is between 7-8 AM (07-08 h). Bearing in mind nothing but your own internal “clock,” how do you think you would perform?

[4] Would be in good form
[3] Would be in reasonable form
[2] Would find it difficult
[1] Would find it very difficult

10. At approximately what time in the evening do you feel tired, and, as a result, in need of sleep?

[5] 8:00 PM–9:00 PM (20:00–21:00 h)
[4] 9:00 PM–10:15 PM (21:00–22:15 h)
[3] 10:15 PM–12:45 AM (22:15–00:45 h)
[2] 12:45 AM–2:00 AM (00:45–02:00 h)
[1] 2:00 AM–3:00 AM (02:00–03:00 h)

11. You want to be at your peak performance for a test that you know is going to be mentally exhausting and will last two hours. You are entirely free to plan your day. Considering only your “internal clock,” which one of the four testing times would you choose?

[6] 8 AM–10 AM (08–10 h)
[4] 11 AM–1 PM (11–13 h)
[2] 3 PM–5 PM (15–17 h)
[0] 7 PM–9 PM (19–21 h)

12. If you got into bed at 11 PM (23 h), how tired would you be?

[0] Not at all tired
[2] A little tired
[3] Fairly tired
[5] Very tired
MORNINGNESS-EVENINGNESS QUESTIONNAIRE

Page 4

13. For some reason you have gone to bed several hours later than usual, but there is no need to get up at any particular time the next morning. Which one of the following are you most likely to do?

[4] Will wake up at usual time, but will not fall back asleep
[3] Will wake up at usual time and will doze thereafter
[2] Will wake up at usual time, but will fall asleep again
[1] Will not wake up until later than usual

14. One night you have to remain awake between 4-6 AM (04-06 h) in order to carry out a night watch. You have no time commitments the next day. Which one of the alternatives would suit you best?

[1] Would not go to bed until the watch is over
[2] Would take a nap before and sleep after
[3] Would take a good sleep before and nap after
[4] Would sleep only before the watch

15. You have two hours of hard physical work. You are entirely free to plan your day. Considering only your internal “clock,” which of the following times would you choose?

[4] 8 AM–10 AM (08–10 h)
[3] 11 AM–1 PM (11–13 h)
[2] 3 PM–5 PM (15–17 h)
[1] 7 PM–9 PM (19–21 h)

16. You have decided to do physical exercise. A friend suggests that you do this for one hour twice a week. The best time for her is between 10-11 PM (22-23 h). Bearing in mind only your internal “clock,” how well do you think you would perform?

[1] Would be in good form
[2] Would be in reasonable form
[3] Would find it difficult
[4] Would find it very difficult
17. Suppose you can choose your own work hours. Assume that you work a five-hour day (including breaks), your job is interesting, and you are paid based on your performance. At *approximately* what time would you choose to begin?

[5] 5 hours starting between 4–8 AM (05–08 h)
[4] 5 hours starting between 8–9 AM (08–09 h)
[3] 5 hours starting between 9 AM–2 PM (09–14 h)
[2] 5 hours starting between 2–5 PM (14–17 h)
[1] 5 hours starting between 5 PM–4 AM (17–04 h)

18. At *approximately* what time of day do you usually feel your best?

[5] 5–8 AM (05–08 h)
[4] 8–10 AM (08–10 h)
[3] 10 AM–5 PM (10–17 h)
[2] 5–10 PM (17–22 h)
[1] 10 PM–5 AM (22–05 h)

19. One hears about “morning types” and “evening types.” Which one of these types do you consider yourself to be?

[6] Definitely a morning type
[4] Rather more a morning type than an evening type
[2] Rather more an evening type than a morning type
[1] Definitely an evening type

___ Total points for all 19 questions
MORNINGNESS-EVENINGNESS QUESTIONNAIRE

Page 6

INTERPRETING AND USING YOUR MORNINGNESS-EVENINGNESS SCORE

This questionnaire has 19 questions, each with a number of points. First, add up the points you circled and enter your total morningness-eveningness score here:

Scores can range from 16-86. Scores of 41 and below indicate "evening types." Scores of 59 and above indicate "morning types." Scores between 42-58 indicate "intermediate types."

<table>
<thead>
<tr>
<th>Score</th>
<th>16-30</th>
<th>31-41</th>
<th>42-58</th>
<th>59-69</th>
<th>70-86</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>definite evening</td>
<td>moderate evening</td>
<td>intermediate</td>
<td>moderate evening</td>
<td>definite morning</td>
</tr>
</tbody>
</table>

Occasionally a person has trouble with the questionnaire. For example, some of the questions are difficult to answer if you have been on a shift work schedule, if you don't work, or if your bedtime is unusually late. Your answers may be influenced by an illness or medications you may be taking. If you are not confident about your answers, you should also not be confident about the advice that follows.

One way to check this is to ask whether your morningness-eveningness score approximately matches the sleep onset and wake-up times listed below:

<table>
<thead>
<tr>
<th>Score</th>
<th>16-30</th>
<th>31-41</th>
<th>42-58</th>
<th>59-69</th>
<th>70-86</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleep onset</td>
<td>2:00-3:00 AM (02:00-03:00 h)</td>
<td>12:45-2:00 AM (00:45-02:00 h)</td>
<td>10:45 PM-12:45 AM (22:45-00:45 h)</td>
<td>9:30-10:45 PM (21:30-22:45 h)</td>
<td>9:00-9:30 PM (21:00-21:30 h)</td>
</tr>
<tr>
<td>Wake-up</td>
<td>10:00-11:30 AM (10:00-11:30 h)</td>
<td>8:30-10:00 AM (08:30-10:00 h)</td>
<td>6:30-8:30 AM (06:30-08:30 h)</td>
<td>5:00-6:30 AM (05:00-06:30 h)</td>
<td>4:00-5:00 AM (04:00-05:00 h)</td>
</tr>
</tbody>
</table>

If your usual sleep onset is earlier than 9:00 PM (21:00 h) or later than 3:00 AM (03:00 h), or your wake-up is earlier than 4:00 AM (04:00 h) or later than 11:30 AM (11:30 h), you should seek the advice of a light therapy clinician in order to proceed effectively with treatment.

We use the morningness-eveningness score to improve the antidepressant effect of light therapy. Although most people experience good antidepressant response to light therapy when they take a regular morning session using a 10,000 lux white light device (see www.cet.org for recommendations) for 30 minutes, often this will not give the best possible response. If your internal clock is shifted relative to external time (as indirectly measured by your morningness-eveningness score), the timing of light therapy needs to be adjusted.

The table at the top of the next page shows the recommended start time for light therapy for a wide range of morningness-eveningness scores. If your score falls beyond this range (either very low or very high), you should seek the advice of a light therapy clinician in order to proceed effectively with treatment.
Identification of Researchers: This research is being done in accordance with the thesis by Jenna Carducci, a graduate student in the Department of Nutrition and Kinesiology.

Purpose of the Study: The purpose of this study is to find out whether chronotype has a relationship with maximal oxygen consumption, energy substrate usage, and/or rating of perceived exertion during maximal testing at extreme ends of the day.

Request for Participation: We are inviting you to participate in a study on chronotype and exercise performance. It is up to you whether you would like to participate. If you decide not to participate, you will not be penalized in any way. You can also decide to stop ongoing testing at any time without penalty. You may withdraw your data at the end of the study. If you wish to do this, please tell us before you turn in your materials. Once you turn in the materials, we will not know which survey or test is yours.

Exclusions: You must be at least 18 years of age to participate in this study. You must be recreationally active (at least 150 minutes of moderate-intensity exercise, at least 75 minutes of vigorous-intensity exercise, or a combination of both in a week’s time). You must not be recommended to or required to have medical clearance before participating in exercise. You must not have been diagnosed with a cognitive disability at any point in your life. You must not be suspected of being pregnant. You must not have a dairy intolerance, a nut allergy, or a specific food allergy.

Description of Research Method: This study involves completing questionnaires, a screening and familiarization trial, and two exercise testing sessions. A few, simple questionnaires will determine your eligibility to participate. The familiarization trial will provide you with a familiarization about what will occur during testing sessions. Exercise tests will provide the research team with valuable data about your exercise performance at different times during the day. The data will be shared with you and described to you at the conclusion of the study. The eligibility screening and familiarization visit will take about one hour to finish. The exercise testing sessions will take about one hour to finish. You will be informed of the purpose of the study at the screening visit. You are free to ask questions at any time. Please note that we cannot give you your individual results until all visits are complete.

Privacy: All of the information we collect will be confidential. We will not record your name, student number, or any information that could be used to identify you. We will keep all data stored in a locked cabinet in an office. Electronic data will be stored on password protected computers.

Explanation of Risks: The risks associated with participating in this study are similar to the risks of vigorous exercise. You may feel physical and emotional discomfort with maximal exercise testing and/or answering the questionnaires and having data collected about your body. There is a very low risk of physical injury or death to occur. Any medical treatments provided if an injury occurs will be at the expense of the participant.
**Explanation of Benefits:** You will benefit from participating in this study by receiving information on your aerobic ability. In addition, you will be informed about your maximal heart rate. These can be valuable training tools. You will also receive information about your chronotype and body composition.

**Questions:** If you have any questions about this study, please contact the primary investigator, Jenna Carducci. She can be reached at carducci@ucmo.edu or at (660) 543-4463. You may also contact the faculty advisor, Dr. Matthew Garver at garver@ucmo.edu or (660) 543-4629. If you have any questions about your rights as a research participant, please contact the UCM Research Compliance Officer at 660-543-8562. If you would like to participate, please sign a copy of this letter and return it to me. The other copy is for you to keep.

I have read this letter and agree to participate.

Participant Signature: ________________________________

Date: ________________________________

Research Team Member Signature: ________________________________

Date: ________________________________
Dear Jenna Carducci:

Your research project, 'The relationship between chronotype, VO2max, RER, and RPE during exercise at extreme ends of the day', was approved by the University of Central Missouri Human Subjects Review Committee on 3/23/2018. You may collect data for this project until 3/23/2019. Your informed consent is also approved until 3/23/2019.

If an adverse event (such as harm to a research participant) occurs during your project, you must IMMEDIATELY stop the research unless stopping the research would cause more harm to the participant. If an adverse event occurs during your project, notify the committee IMMEDIATELY at researchreview@ucmo.edu.

The following will help to guide you. Please refer to this letter often during your project.

- If you wish to make changes to your study, submit an "Amendment" through Blackboard under the "Amendment and Renewals" tab. **You may not implement changes to your study without prior approval of the UCM Human Subjects Review Committee.**

- If the nature or status of the risks of participating in this research project change, submit an "Amendment" through Blackboard under the "Amendment and Renewals" tab. **You may not implement changes to your study without prior approval of the UCM Human Subjects Review Committee.**

- If you are nearing the expiration date for collecting data for this project (3/23/2019) and you have not finished collecting data:
  1. submit your project application via Blackboard under the "Amendment and Renewals" tab (include any revisions and/or amendments approved since you submitted your application initially)
  AND
  2. submit a "Renewal Report" through Blackboard under the "Final/Renewal Report" tab.

- When you have completed your collection of data, please submit the "Final Report" found on Blackboard under the "Final/Renewal Report" tab.

If your protocol contained a consent form and the consent form was approved, you will receive an additional e-mail. The e-mail will contain a copy of your consent form with an approval stamp in the top right corner. Do not begin data collection until you receive a copy of your consent form with an approval stamp. Note: One year after your protocol's approval date, a request for renewal OR a final project report is required.

If you have any questions, please feel free to contact me at researchreview@ucmo.edu.

Sincerely,

Equal Education and Employment Opportunity
Kathy Schnakenberg
Program Administrator/Research Compliance Officer
Office of Sponsored Programs and Research Integrity
University of Central Missouri
cc: garver@ucmo.edu

Equal Education and Employment Opportunity
Amendment  
3/28/2018  
Protocol Number: 1048  

Dear Jenna Carducci:  

Your request to amend your research project, 'The relationship between chronotype, VO2max, RER, and RPE during exercise at extreme ends of the day', was approved by the University of Central Missouri Human Subjects Review Committee on 3/28/2017. You may collect data for this project until 3/23/2019. Your informed consent is also approved until 3/23/2019.  

**If an adverse event (such as harm to a research participant) occurs during your project, you must IMMEDIATELY stop the research unless stopping the research would cause more harm to the participant.** If an adverse event occurs during your project, notify the committee IMMEDIATELY at researchreview@ucmo.edu.  

The following will help to guide you. Please refer to this letter often during your project.  

- If you wish to make changes to your study, submit an "Amendment" through Blackboard under the "Amendment and Renewals" tab. **You may not implement changes to your study without prior approval of the UCM Human Subjects Review Committee.**  

- If the nature or status of the risks of participating in this research project change, submit an "Amendment" through Blackboard under the "Amendment and Renewals" tab. **You may not implement changes to your study without prior approval of the UCM Human Subjects Review Committee.**  

- If you are nearing the expiration date for collecting data for this project (3/23/2019) and you have not finished collecting data:  
  1. submit your project application via Blackboard under the “Amendment and Renewals” tab (include any revisions and/or amendments approved since you submitted your application initially)  
  AND  
  2. submit a “Renewal Report” through Blackboard under the “Final/Renewal Report” tab.  

- **When you have completed your collection of data, please submit the “Final Report” found on Blackboard under the “Final/Renewal Report” tab.**  

If you have any questions, please feel free to contact me at researchreview@ucmo.edu.  

Sincerely,  

Kathy Schnakenberg  
Program Administrator/Research Compliance Officer  
Equal Education and Employment Opportunity
Office of Sponsored Programs and Research Integrity
University of Central Missouri
cc: garver@ucmo.edu